MEASURING THE NUMBER OF CALORIES IN SUNLIGHT

OBJECTIVES

The student will do the following:

1. Define calorie.
2. Determine the amount of heat available from the sun in his/her area.
3. Compare the absorption of solar energy by three different collectors.
4. Define the solar constant.
5. Offer several explanations for discrepancies between the data collected and the solar constant.

SUBJECTS:

General science, Physical Science, Environmental Science.

TIME:
2 class periods.

MATERIALS:
For each group of 3 students: Celsius thermometer, graduated cylinder, grease pen (or soot, carbon black, or black tape), magnifying glass, metric ruler, test tube rack, 3 test tubes, watch or timer, student sheets (included).

BACKGROUND INFORMATION

Unimaginably vast amounts of solar energy reach the earth each day. Some is reflected or refracted back into space, some is absorbed by the earth‘s atmosphere, and some reaches the surface of the earth. Although the amount reaching the earth’s surface is huge, not all of it is useful to human beings. The energy is diffuse and must be captured and concentrated before we can use it for most of the purposes for which we require energy. Secondly, energy conversion (from one form to another) cannot be carried out at 100 percent efficiencies.

Solar scientists have determined that the amount of solar energy reaching the earth’s atmosphere is 1.94 calories per square centimeter per minute. This value is known as the solar constant. Obviously solar collectors will not receive this amount of energy because of the atmosphere’s absorption and reflection of some of the energy. Other factors also affect the collection of solar energy; latitude, altitude, weather conditions, seasons of the year, orientation of the collector, and other factors all come into play.

PROCEDURE

I. Review with the class the definitions of the terms *calorie*, *centimeter*, and *milliliter*. Introduce the solar constant to the students. The solar constant is a computed average for the amount of heat energy reaching the earth’s atmosphere in a unit of time. It is defined as being 1.94 calories per square centimeter per minute (1.94 cal cm^2min).

II. Divide the students into groups of three. Give each group the listed materials and review the steps in the instructions for the experiment (see the student sheet, included).

III. Have the students complete the experiment, filling out the data table on the student sheet as they go.

IV. Continue with the follow-up below.

FOLLOW-UP

I. How did the solar heat absorptions determined in this experiment compare to the solar constant? (You may want to have the groups average their three trials for each test tube and record the figures on the chalkboard or a chart.)

II. What are some possible explanations for why the collected data differ from the solar constant? Can your students formulate hypotheses and design experiments to test some of these explanations?

The solar constant is a value that does not apply directly to solar collectors located on the earth's surface. It does not take into consideration the absorption of energy by the atmosphere. Because of this absorption, it is not possible to actually receive 1.94 $cal/cm^2/min$ in a collector on the earth's surface. It may be possible, on the other hand, to attain values greater than this in the experiment. Errors in calculations, rounding of figures, errors in measurement, and other faults in carrying out the procedure, as well as faults in the procedure itself, all may affect the experiment's outcome.

III. How do the three test tubes differ in their abilities to trap heat from sunlight? (Look again at the averages of the trials.)

IV. Have the students determine, using their figures, the amount of heat absorbed by a typical black and glass solar collector with dimensions of 2 x 1.5 m.

The area of the collector is $3m^2$. This is $30,000cm^2$. Determine which test tube most closely approximates a solar collector and use the calorie absorption average for that test tube. Multiply the figure by 30,000. (Remember that this figure represents energy absorption for one minute. What about for an hour? A day?)

V. How does the time of day affect the availability of solar heat?

At noon, the sun's rays are most nearly perpendicular to our area on the earth. This means that they must pass through less atmosphere than at any other time of the day. The less atmosphere the rays pass through, the more energy is available. In the morning and afternoon, however, the rays strike the earth's surface more obliquely and must pass through more atmosphere than at noon. Less energy is available.

VI. Why doesn't the earth itself overheat?

Some of the heat absorbed by the earth's atmosphere and surface is radiated into space during the night. Earth's 24-hour rotation period helps maintain a temperature suitable for the great variety of life forms on this planet.

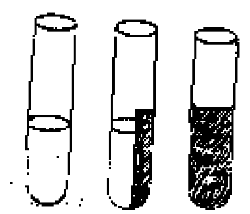
MEASURING THE CALORIES IN SUNLIGHT

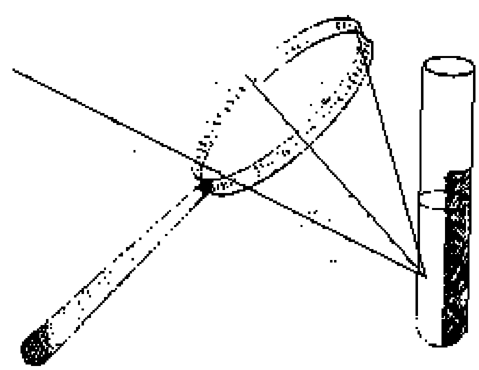
Instructions

1. Prepare the test tubes. Use black tape, a grease pencil, or another provided material to cover the entire bottom portion of one test tube and one half of the bottom of a second test tube. (See the illustration below.) Leave the third test tube clear.

2. Determine the area of the hand lens (magnifying glass). Measure the diameter of the lens. Find the radius by dividing the measurement in half. Record the radius across the data table. Compute the area of the lens using the formula $A = \pi r^2$, where A is the area, $\pi = 3.14$, and r^2 is the square of the radius. Record the area across the data table.

3. Choose one of the test tubes. Using the graduated cylinder, measure 10 ml of distilled water and pour it into the test tube. Measure and record the temperature of the water. Place the test tube in the test tube rack and hold the hand lens to focus the sun's rays directly into the water. (See the illustration.) Do this for five minutes. Measure and record the final temperature of the water. Compute and record the change in temperature. Repeat this procedure twice more (for a total of three trials).





4. Repeat the entire procedure in III for each of the other two test tubes.

5. Compute the calories of heat energy from sunlight absorbed by the water in each trial. Multiply the mass of the water by the number of degrees the temperature changed. (Remember that one milliliter of water has a mass of one gram.) Record these figures in the data table.

6. Compute the number of calories of energy received per square centimeter (of lens surface) per minute in each trial. Record these figures in the data table.

7. Compute the percentage efficiency of your collection of solar energy as compared to the solar constant. Divide each of your figures by 1.94 $cal/cm^2/min$ and multiply by 100 to get a percentage. Record these figures in the data table.

DATA TABLE

	CLEAR			HALF-BLACK			BLACK		
	TRIAL #			TRIAL #			TRIAL #		
	1	2	3	1	2	3	1	2	3
Radius of lens (cm)									
Area of lens (cm^2; compute $A = \pi r^2$)									
Water (ml)	10	10	10	10	10	10	10	10	10
Initial temperature (°C)									
Final temperature (°C)									
Change in temperature (°C; computed)									
Time (minutes)	5	5	5	5	5	5	5	5	5
Calories absorbed									
Calories/cm^2/minute									
Solar constant (cal/cm^2/min)	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94	1.94
Percent efficiency compared to solar constant									